ECE 403: Senior Design II

Options Considered Document

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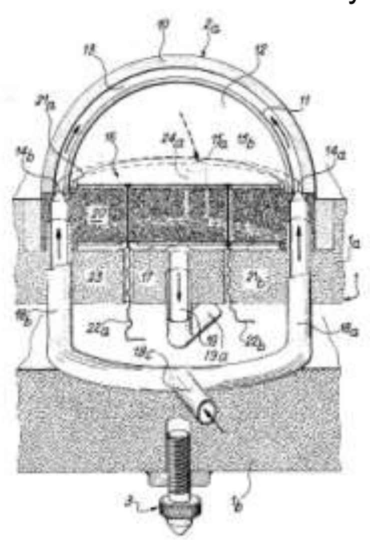
Introduction:

The device we are designing is a data acquisition system used to measure the amount of available power from solar and wind in a given area. In designing an off-grid renewable energy system for a remote location, it can sometimes be difficult to determine what the capacity of the available renewable power sources of that location may be. This project was the result of a brainstorming session with our advisors while trying to find the best way to measure the amount of solar and wind power that can be harnessed at a certain location. This system allows the design of an off-grid renewable energy system to be specifically created to best take advantage of the climate and other features of the specific location. The data that the system will log can be used by the consumer to make a more informed decision as to the type of renewable energy power system that would be best suited to their specific application and potentially save them money.

Previous Work:

Pyranometers

Pyranometers are devices for measuring solar irradiance. They measure the solar radiation flux density in watts per meter square across the spectrum of wavelengths for solar radiation (300 to 2800 nm). The image included is from U.S. Patent #3876880 titled “Pyranometer for the Measurement of Solar Radiation”.



Miniature Remote Weather Stations / Anemometers

Existing products that are similar to the solar and wind energy data acquisition device that we plan on designing and producing include miniature weather monitoring stations. These systems are designed to measure the temperature, wind direction and speed, precipitation, barometric pressure, and other factors related to weather and climate. We plan on implementing some features of these existing systems into the design of our system, but our system will differ in that instead of taking weather measurements, we will be using these types of devices to specifically measure the energy potential of wind and solar power at the location.

There are devices that exist for measuring and collecting data on wind velocity, pressure and direction and logging that data in various ways. We plan on using this data to specifically determine the amount of available energy that can be harnessed from the wind to use in an off-grid renewable energy power system. There are many different varieties of anemometers, which we discuss in more detail in our Design Options section. Shown here
is one example of an Ultrasonic Wind and Weather Station from Maretron. (Model # 11115672 / Manufacturer # WSO100-01). It measures wind speed and direction, air temperature, barometric pressure, and relative humidity.

Design Options:

Method for Measuring Solar Power Potential

There are several different devices and components available for measuring the solar radiation or energy available from solar power. We considered several options for our design. A brief description of each option and their advantages and disadvantages are listed below.

Photoresistor

A photoresistor is a component with two leads using a cadmium sulfide (CdS) element that shows a decrease in resistance when illuminated. In the dark, the resistance of this component is very high, and when exposed to light, the resistance drops dramatically.

Advantages:

- CdS Photoresistors are cheap.
- Very high sensitivity compared to other sensors.

Disadvantages:

- More sensitive to green light, which in the spectrum of sunlight is more intense higher in the atmosphere. Nearer to sea level, the wavelength of solar radiation tends toward the high end of the visible spectrum and into the infrared spectrum.
- The relationship between resistance and light intensity is logarithmic, making accurate calibration more difficult.
- May not be the most accurate or rugged choice for our application.

Phototransistor

A phototransistor is similar to a standard transistor, but it often does not have a lead attached to the base region. The collector-base PN junction is sensitive to light, producing a base current proportional to the intensity of the light shining on it. This base current initiates a collector current which is also proportional to the intensity of the light.

Advantages:

- More sensitive than a photodiode.

Disadvantages:

- Collector current is proportional to the light intensity, we would rather have voltage proportional to light intensity.
- Slower switching speed than photodiode.
- Can be used to make simple light meters or light-sensitive switches.

Photodiode

The mechanism of operation of a photodiode is similar to that of a miniature solar cell. When used as light detectors, they are reverse-biased, and the reverse current is linearly proportional to the intensity of the light striking the diode.

Advantages:

- Relationship between reverse current and light intensity is linearly proportional.
- Response time is fast, on the order of nanoseconds.
- Photodiodes are cheap.

Disadvantages:

- Not as sensitive as phototransistors or photoresistors.
- Usually only useful for simple light meters or light sensitive switches.

Photovoltaic Cell / Solar Panel

Advantages:

- Can be used as light detector and voltage supply if solar energy is sufficient.
- Sensitive to visible and near infrared light.
- Often designed for use in outdoor environments.
- Less expensive than pyranometers, can easily fit into our budget.

Disadvantages:

- Larger than simple photosensitive components.
- More costly than photoresistors, phototransistors, and photodiodes.

Pyranometer

Advantages:

- Most accurate method for measuring solar radiation.
- Designed for outdoor use, rugged.

Disadvantages:

- Prohibitively expensive for use in our device (simple pyranometers cost at least $200).

As of right now, the option for measuring solar power potential that we feel best fits our needs and will allow us to fulfill our requirements for the design project is the photovoltaic cell / solar panel. We plan on investigating this option as both a source of power for charging our battery supply and as a method for measuring solar power availability.

Method for Measuring Wind Power Potential

The best option for measuring wind power potential requires us to measure the speed of the wind and possibly the direction of the wind. The best device for measuring wind speed is an anemometer, of which there are several different types. We

considered four different types of anemometers. A brief description of each type, along with some advantages and disadvantages of each, are included below.

Cup or Rotational Anemometer

In this type of anemometer, three or four cups are arranged around a vertical axis and when the wind presses against them, the cups rotate around the axis. The faster the wind speed, the faster the cups rotate, and the rotation of the anemometer can be analyzed to find the speed of the wind.

Advantages:

- Most widely available type of anemometer.
- Cheapest variety of anemometer.
- Easy to configure for a digital readout.
- Designed for outdoor use.

Disadvantages:

- Only measures wind velocity, does not account for wind direction.
- Some types may not be rugged enough for our application.

Windmill Anemometer

The windmill anemometer is similar in design to the classic weathervane seen on barns. It consists of a propeller at the front of the device and a tail section. Pressure from the wind causes the propeller to spin, and the tail fin aligns the anemometer with the wind direction. The rotational speed of the propeller can be used to determine the wind velocity.

Advantages:

- Measures both wind velocity and direction.
- Designed for outdoor use.

Disadvantages:

- More expensive than cup anemometers that just measure wind velocity.
- It may be unnecessary for us to measure wind direction for our application.

Hot Wire / Thermal Flow Anemometer

A hot wire anemometer measures both the wind speed and pressure. It is a long rod with a hot wire or bead at the tip. As wind moves over the hot wire, the wire is cooled, and there is a direct relationship between the rate of the airflow over the wire and how cool the wire becomes.

Advantages:

- Simple construction / no moving parts.
- Cheapest type of anemometer.

Disadvantages:

- Does not measure wind direction.

- May not be practical for our application. This type of anemometer is often used in HVAC systems to measure airflow through building ducts.

Ultrasonic Anemometer

Ultrasonic anemometers use disruptions in sonic pulses to measure wind data. They send sonic pulses across a path to a sensor. As wind speeds increase, the disruption in these pulses increases. This type of sensor typically has four sensors arranged in a square pattern.

Advantages:

- No moving parts.
- Rugged solid state design.
- Very sensitive, can detect small changes in wind.
- Can measure both wind velocity and direction.

Disadvantages:

- Prohibitively expensive for our application (most are $600 or greater).

The method for measuring wind power potential we feel will work best for our design is either the cup anemometer or the windmill anemometer. Further investigation and research is required to determine how important it will be for us to measure the wind direction. Whether or not we need to measure wind direction along with speed will be the determining factor as to the anemometer we choose to include in our system. The ultrasonic anemometer would be ideal for our application, but the cup or windmill anemometer is the much more economical choice.

Method for Measuring Temperature

Measurement of temperature at the location is another requirement of our system. We have considered two different options for temperature measurement. A brief description of each, along with advantages and disadvantages of each, is included below

Thermistor

This is a type of resistor whose resistance varies with temperature. They are generally made of ceramic or polymer. As the temperature of the thermistor increases, the resistance of the thermistor decreases, giving an inversely proportional relationship between temperature and resistance.

Advantages:

- High precision over a limited temperature range
- Relatively inexpensive

Disadvantages:

- Linear approximation of temperature-resistance relationship is only applicable over a small range, making calibration more difficult than other available options.

Digital Temperature Sensor IC (Dallas Semiconductor, Jameco Part no. 114382)

This component is a integrated circuit chip produced by Dallas Semiconductor that is designed as a temperature sensor

Advantages:

- Output of this IC is already a 9-bit resolution digital signal, doesn't require an A/D input

Disadvantages:

- Slightly more expensive than thermistor (about $6 per unit).

For temperature sensing, the digital temperature sensor integrated circuit chip from Dallas Semiconductor appears to be the best option. It is not terribly expensive, and it appears that it would be easier to implement in our system than a thermistor circuit which would require more extensive calibration.

Microcontroller Selection

A microcontroller capable of receiving A/D or digital inputs from a solar panel, anemometer, and temperature sensor, and analyzing and storing this data is required. It needs to be able to accept input from three different devices and log and store this data by some method, most likely flash memory. Power consumption should be kept to a minimum, so efficient coding and use of available resources is essential.

Microchip PIC 18F4620

The Microchip PIC 18F4620 is a microcontroller which we both have experience programming for and working with. It is a relatively low-cost, low-power device, but it has the capabilities and features we desire in a microcontroller.

Advantages:

- Easy to use - we have experience using this chip from Embedded Systems (ECE 376).
- Relatively low cost.
- Reliable.
- Information and expertise on programming the PIC is readily available both from NDSU faculty and other resources.
- Low power standby consumption.
- Timers and other features will be useful for limiting power consumption by only taking data readings at certain time intervals.
- Several Input/Output ports if additional features are desired in the future

Disadvantages:

- There are many options available for microcontrollers with a wide range of prices, features, and performance. If we find that we need more power or performance, we may have to consider a different microprocessor in the future.

Electrocorder Three Channel Voltage Logger Model DC-3V-60

The Electrocorder Three Channel Voltage Logger is a standalone data logging device which accepts three voltage inputs and can be used to monitor the voltage of many applications, including photovoltaic cells and charging circuits.

Advantages:

- Constant sampling, misses very little data.
- Accurately records DC voltages up to 60Vdc.
- Data can be uploaded to a PC for analysis with free Electrosoft software.
- Up to 300 days of continuous recording.
- Accurate to within 2% of voltage reading for most applications.
- Would require less coding for the microcontroller.

Disadvantages:

- Unsure of cost at this time, may be out of our budget limitations.

Right now, we have made phone calls to find out what the price of the Electrocorder Voltage Model is. Until we have more information regarding the cost of this system, we are going to consider using the PIC as our microcontroller for receiving input from devices and data logging.

Data Storage Selection

The data storage capacity of our system has to be sufficient enough to hold several months worth of wind velocity, solar intensity, and temperature data. The amount of storage actually required will be determined by our sampling rate, data resolution, and length of operation. We are considering several different types of flash memory for storage, including SD memory, or USB flash drives. More research into this topic will be required. As of now, we have the knowledge to be able to acquire a serial data signal from the PIC and sent that via serial port to a PC. Investigating methods for storing this data easily and efficiently will be something that we will look into further as we continue with our design. The advantages and disadvantages of these different data storage formats will be something that we will consider when we are able to look into this topic in more depth.

Circuit Housing Selection

Durable and affordable housing for our circuit is a necessity for our application. The device will be exposed to the elements, so it should be as weather-resistant as

possible. There are a wide variety of different circuit housing options available. We may end up building one of our own, ordering a prefabricated one, or having one fabricated to our specifications, depending on several factors, including the size and complexity of our finished circuit, and the cost of different housing options.

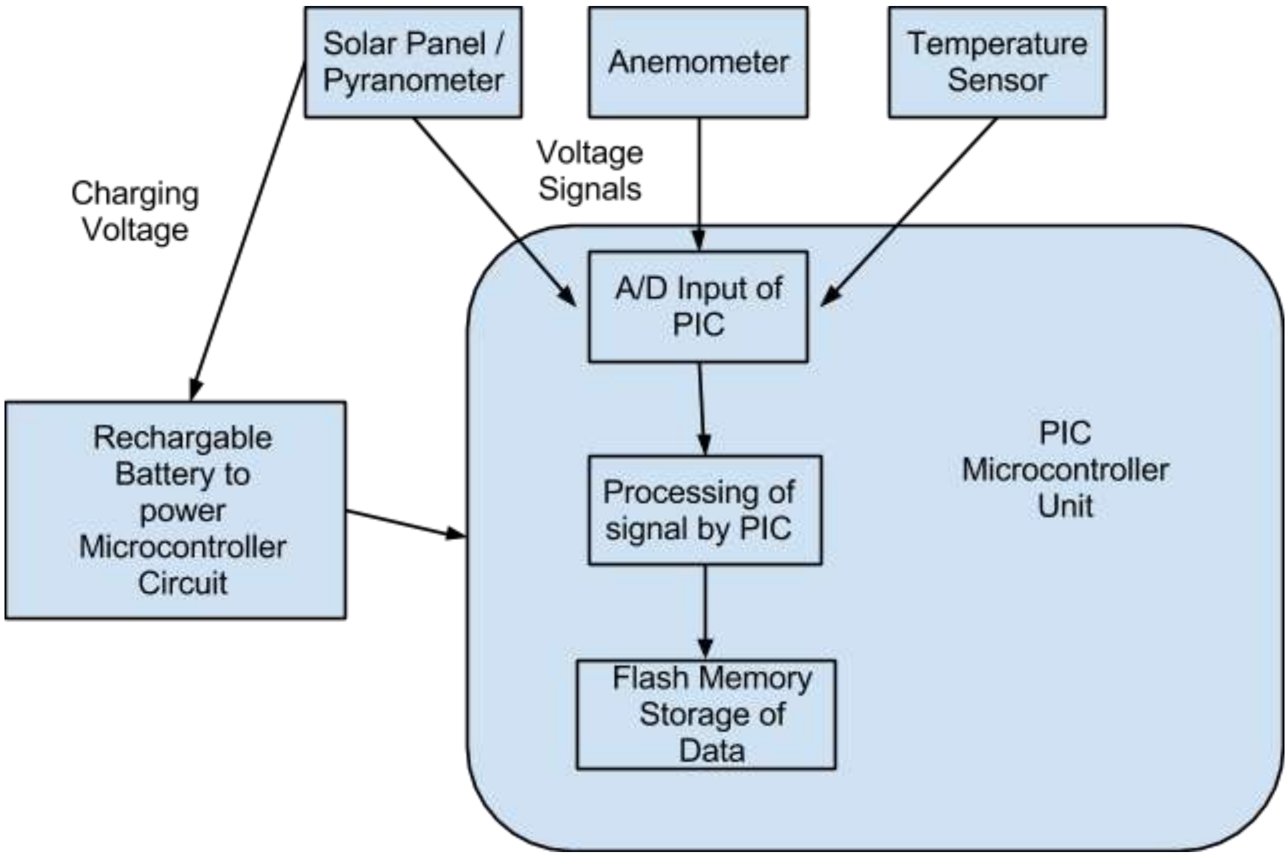
Cable/Conduit Selection

Cables leading to and from the anemometer and solar cells must be either weather-resistant or sheathed in a weather-resistant conduit. They may be exposed to harsh weather and wildlife, so they need to be protected against several different types of damage. There are many commercially available conduits made of a wide variety of durable materials. This is a design consideration that we will have to consider closer to the end stages of our final design, so right now, our options for cables/conduits are pretty open. We don't wish to limit ourselves in this area until we are sure of the other components we will be using for our design.

Method of Powering

We plan on powering the system with a rechargeable battery that will be charged using the solar panel. We need to use a power source that will be able to provide the necessary power for the device over an extended period of time, possibly as long as 3 months. We are considering a 6V golf cart type DC battery for our design.

Block Diagram of Solar/Wind Power Data Logger:



Budget

Item	Description	Purpose	price/unit	# of units	total
Brunton Solarflat2 Solar Panel	6V, 2 Watts, weatherproof	charging the 6V battery	$25.00	1	$25.00
Rechargeable Battery LC-R0612P1	6V golf cart battery, Lead Acid	store energy in a chemical reaction to power PICs and data logger	$30.80	1	$30.80
Materials	lumber, metal fasteners, mounting equipment, wires, conduit, resistors, capacitors, inductors	building project	$50.00	1	$50.00
PIC 16F876A	micro processor	logging/interpreting data	$7.70	2	$15.40
Enclosure	weather/animal resistant enclosure	houses: battery, PICs, Temperature sensor, and data logger	$100.00	1	$100.00
DS1620 Temp Sensor	IC measures temperature	logging accurate temperatures on environment	$5.95	1	$5.95
Anemometer	simple anemometer	measuring wind speed and direction.	$100.00	1	$100.00
Flash Drive or SD Card	USB 8MB flash Drive or SD card	storing data points for (anemometer, solar panel, and thermal sensor)	$10.00	1	$10.00
Simple Logger II DC Voltage Model L432	Logs voltages from two different channels, can run up to 300 days	logs data for up to eight weeks	$379.00	1	$379.00
				TOTAL	**$716.15**

Timeline

			Week																														
Name	**Weeks**	**Who**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Requirements Capture Meeting	3	Both			X																												
Requirements Capture Document	4	Both				X																											
Options Considered	5,6	Both					X	X																									
>>>Budget, Timeline	5,6	Adam					X	X																									
>>>Previous work, Options Considered, Intro/Summary	5,6	Darrin							X																								
Order Parts	7	Both								X	X	X	X	X																			
Program PIC	8,9,10,11,12	Both								X	X	X	X	X																			
>>>Breadboard PIC	8,9,10,11,12	Both								X	X																						
Calibrating Components	8,9	Both								X																							
>>>Anemometer	8	Both									X																						
>>>Solar Panel	9	Both								X																							
>>>Temp Sensor	8	Both												X																			
Progress Report: Bring together all individual parts	12	Both												X	X																		
Power Consumption, Power Requirements	12,13	Both												X	X	X	X																
Troubleshooting and revisions	12,13,14,15	Both																X															
Presentation, end of semester one	**16**	**Both**																**X**															
Designing PCB layout	17,18	Both																	X	X													
>>>Shipping out PCB layout	18	Both																		X													
Fabricating Housing Unit	17,18,19	Both																	X	X	X												
>>>weather proofing	18	Both																		X													
>>>Fastening connectors, wires, sensors, battery and PICs	19	Both																			X												
Fabricating Mounting brackets	20,21	Both																				X	X										
>>>Solar Panel	20	Both																				X											
>>>Anemometer	21	Both																					X										
Assembling all components	21,22,23	Both																					X	X	X								
Testing entire system (in lab) using pre-determined voltage inputs for sensors	24,25	Both																								X	X						
Troubleshooting and revisions	26	Both																										X					
Testing system (in field)	27,28	Both																											X	X			
Going over data collected and making minor changes	29	Both																													X		
Preparing for final presentation	30,31	Both																														X	X
Presentation, Final Product	32	Both																															

Summary:

We have shown that there are many different options to consider in the design and construction of our solar / wind power data logger system. Many of our decisions for this project involve choosing components and devices which will be able to withstand the elements, be reliable and relatively autonomous, and minimize power consumption of the system while trying to stay within the limits of the provided project budget. As can be seen from our timeline, we plan to have a breadboarded prototype of the system with the necessary programming and coding completed by the end of this semester. We will spend the following semester designing a PCB for our circuit and fabricating durable housing and mounting for the device so that we will have a fully functional solar and wind power data logging system that can be deployed at a location to measure sources of renewable energy.

The data acquisition device that we plan on designing will be able to solve the problem of not knowing what type of renewable energy system is best for a certain location. By measuring the amount of available solar energy and wind energy at a location, we can provide a recommendation as to what type of off-grid power system would be most feasible for the location.